Product User Manual

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Counter-Top Microwave Dryer
CTMD
(50 Hz Model)

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CTMD s/n _____

Developed for

EPRI

by

Thermo Energy Corporation

and

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REVISION HISTORY			
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DOCUMENT CONVENTIONS

NOTE: *Means the reader should take note. Notes contain helpful information, suggestions, or references to other sections, chapters, or documents.*

CAUTION: *Means the reader should be careful. You are doing something that might result in equipment damage or loss of data.*

WARNING: *Means danger. A situation exists that could cause bodily injury or death. All personnel must be aware of the hazards involved with high voltage electrical circuitry and high power microwave devices.*

WARNING

The microwave dryer described in this manual is capable of producing a microwave field that is potentially hazardous to operating personnel. The unit must never be connected or operated in a manner that allows a field in excess of 10 milliwatts per square centimeter to be generated in an area accessible to operating personnel. Contact GAE, Inc. for technical support prior to installation and/or operation of these units if there is any question or concern about microwave leakage.

All electrical cable connections must be secure prior to operation. Never operate the microwave dryer without a properly rated absorbing load inside the oven cavity. To ensure safe operation and prevent microwave leakage, the equipment must be periodically inspected and maintained as required or recommended.

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ATTACHMENTS:

Document Type	Number	Title
Drawing	910076	Outline Drawing
Drawing	910415	Schematic Diagram, CTMD
Drawing	910366	Schematic Diagram, Control PC Board
Chart		CTMD Operation Flow Chart

INTRODUCTION

The Counter-Top Microwave Dryer (“CTMD”) is the result of an extensive program funded by EPRI to develop microwave fabric drying technologies. The program began by investigating the technical and economic feasibility of full size microwave tumble dryers for residential and commercial use. The inherent advantages associated with enhanced fabric care and performance were successfully demonstrated as were several technological advances addressing the microwave related safety issues. The features and benefits of these full size models were then incorporated into the reduced size design of the CTMD.

The CTMD is designed as a consumer appliance intended primarily for drying a variety of fabric articles that are not normally dried in a conventional full size dryer. Its most significant advantages are low temperature drying, gentle tumbling and speed. Thus, and because it is only slightly larger than a microwave oven, the CTMD is ideal for small loads of delicate fabrics such as woolens, silks, nylons and a variety of knitted fabrics.

Development of the CTMD began in 1998 with the construction of a working mock-up used to prove the concept and feasibility of a small microwave tumble dryer. Dubbed the “C&F” prototype, this unit was simply a residential microwave oven modified by adding a rotating basket and enhanced air flow. This was followed by the ground-up design and construction of an “alpha” prototype unit used for functional development and demonstration. The current “beta” prototype incorporates various new features and design improvements resulting from extensive alpha prototype testing.

GENERAL DESCRIPTION

The EPRI Counter-Top Microwave Dryer (“CTMD”) is designed to dry fabric loads up to 1.5 pounds. It utilizes only microwave energy to dry almost any type of fabric load at faster rates and lower temperatures than conventional dryers that use hot air. A microprocessor control system coordinates operation of the dryer by collecting data from a variety of sensors to optimize performance and ensure safety.

The microwave energy is supplied by a single magnetron rated for 1.1kW. Energy efficiency is maximized by ducting the heat dissipated from the magnetron and power supply through the dryer cavity where it assists with moisture vaporization and removal.

User operation of the CTMD is as simple as pressing the Start button after placing a load of wet clothes in the dryer basket. There is no requirement to select load size or dryness setting, although such selections are possible using buttons on the touch keypad. A microprocessor system controls the operation using sensor inputs and displays the status of drying on a liquid crystal display (LCD) located on the front panel.

State-of-the-art safety features protect both the dryer and operator from improper operation and use. A variety of sensors are provided to detect the presence of improper materials in the drying load and shut off the dryer.

There are no special installation requirements for the CTMD as it can be operated using facilities available in most households. The input line power required is 220-240 VAC, 50 Hz, single phase, 10 Amps. There are no requirements for exhaust ducting.

As the CTMD is intended for research and development purposes, a special connector is provided on the back for use in microprocessor programming and parametric data acquisition. Custom data acquisition software is available. Contact GAE, Inc. for more information about the use of this connector.

Electrical Specifications

Microwave Power	1.1 kW (nominal)
Magnetrons	Panasonic 2M210
Line Power Input	220-240 VAC, 50 Hz, Single Phase, 10 Amps (2-wire plus ground)

Mechanical Specifications

Basket Size	13.5” diameter x 13” deep
Basket Capacity	1.5 Pounds (dry weight, 100% moisture retention)
Door Opening	11.25” Dia.
Electrical Input Connector	CEE 7 style plug
Exhaust Duct	2” x 6” Vent located on left side
Free Air Displacement	100 CFM (approximate)
Overall Dimensions	23.14” Wide x 17.28” Deep x 16” High
Weight (approx.)	80 lb. net; 120 lb. shipping

Controls

Cycle Start	Pushbutton
Cycle Stop	Pushbutton
Cycle Select	Pushbutton for “Small”, “Medium” and “Large” load size settings (selection not required for operation)
Dryness	Pushbutton for “Damp”, “Dry” and “Extra Dry” settings (selection not required for operation)
Indicators	4-line Liquid Crystal Display (LCD)

Sensors

Dryer Operation	Load temperature
Thermal Cut-outs	Magnetron, lint burn-off screen
Safety	Door interlock switches, microwave field strength detector, exhaust gas sensors

INSTALLATION

Preliminary Inspection

Upon arrival at the installation site the CTMD should be thoroughly inspected for damage or wear caused during shipping. Any visible damage to the shipping crate or CTMD should be noted and reported immediately to the shipping company in accordance with standard claims procedures.

Facilities Requirements

- Line Power: 220-240 VAC, 50 Hz, single phase, 10 Amps, 2-wire plus ground. Proper earth ground must be provided.
- Ventilation: Air vents are located on the right (intake) and left (exhaust) sides. Minimum clearance of 2” must be provided for proper air flow.
- Environment: Indoors only, must be clean and dry.

Location

The CTMD may be installed and operated on any level surface. Adequate clearance must be provided on the sides to allow sufficient intake and exhaust of ventilated air.

Electrical Connections

- Line Power: Line power connection can be made to a standard CEE 7 style grounded electrical outlet having a 10 Amp rating.
- Programming/Data Acquisition: A 9-pin female subminiature “D” connector located on back panel can be connected to any standard modem or computer serial port. Contact GAE, Inc. for more information about programming and data acquisition software.

BASIC OPERATION

Operation of the CTMD is very similar to that of a conventional residential clothes dryer. A typical sequence of events is as follows:

- Load fabrics to be dried and close door
- Press 'Start' button to begin drying
- Wait for beep signaling end of drying cycle
- Open door and remove dried fabrics

While this operation sequence appears to be relatively simple, there are many subtle aspects of the CTMD's operation as explained below that should be fully understood by the operator.

Initial Power-Up

Upon connecting line power as described in the "Installation" section of this manual, power is applied to the microprocessor controller and various sensors. Line power can remain on indefinitely, so there is no need to turn off and disconnect line power between periods of operation. However, as a safety precaution it is recommended that line power be disconnected during extended periods of non-operation.

NOTE: *The exhaust gas sensors require a warm-up period prior to operation. The sensor manufacturer recommends a minimum of one hour warm-up for stable operation. However, testing has demonstrated that a few minutes is generally sufficient.*

Dryer Loads

The CTMD is designed to accommodate most typical fabrics used in clothing or other standard textile products. However, it should be noted that some fabrics may contain certain materials that will result in fault conditions during the drying process. While the CTMD is designed to protect itself and the operator from such loads, the operator should take necessary precautions to avoid loads containing the following materials:

- Metallic fabrics such as woven metal screens
- Metallic or metalized threads
- Heavily studded, sequined or ornamented fabrics (a few metal studs or metal zippers are generally OK)
- Non-fabric objects such as pencils, cigarette lighters, coins, hair pins, etc.

The CTMD generally performs better and more reliably with full loads than with lighter loads. Also, loads should be evenly wetted as would be typical following a standard wash cycle with spin drying.

CAUTION: *Loads must not contain excessive amounts of moisture such that water is allowed to accumulate inside the dryer cavity and/or drip down from the dryer basket. Failure to prevent water accumulation and dripping may result in electrical damage to the CTMD. Spin drying of all loads prior to microwave drying is highly recommended.*

Drying Cycle Setting

It is not necessary to select the load size before operation. The CTMD is capable of detecting the load size during operation and will make adjustments to the drying process accordingly. However, selecting a load size before operation can be done and will not adversely affect performance.

Cycle Start

Close the dryer door and press the ‘Start’ button to begin the drying cycle. The basket will immediately begin to rotate and the main blower will operate. The LCD will display the status of the cycle by indicating the start of operation of certain functions (basket, blower, microwave, etc.). A cycle timer will also begin incrementing.

NOTE: *When starting the drying cycle for the first time following initial power-up (see above), the gas sensor fault cycle (see below) may be initiated due to insufficient warm-up of the gas sensors. This should not occur during subsequent starts unless line power is turned off and then back on again.*

Cycle Stop

Once started, the drying cycle will continue until one of the following occurs:

- The cycle ends normally when moisture has been sufficiently removed.
- The ‘Stop’ button or the door switch may be pressed to stop the drying cycle at any time and for any reason.
- A fault condition as explain below will stop the drying cycle automatically.

The drying cycle can be restarted following any of the above stop events once the buzzer has sounded. Once restarted the cycle will continue as before and the cycle timer will resume incrementing.

Cycle Reset

The drying cycle can be reset after stopping by pressing the 'Stop' button a second time. This action will reset the cycle timer to zero.

Fault Cycles

The following fault cycles may be initiated during the drying cycle due to abnormal operating conditions.

- Gas Sensor Fault: Gas sensors located in the exhaust air stream can detect the presence of substances that may indicate a hazardous condition (i.e. fabric burning). If such substances are detected the controls will immediately turn off microwave power and ventilate the cavity for thirty seconds. The dryer will then stop operating and the LCD will display a message prompting the user to check the dryer load. The CTMD can then be restarted as usual.
- High Field Strength: Operation of the CTMD with no load will result in high electric fields inside the microwave cavity which can cause damage. The field strength detector will detect such a condition, turn off the dryer and display an error message on the LCD. The dryer can then be restarted as usual.

Lint Filter Cleaning

The lint filter, located on the left side behind the dryer, should be inspected regularly and cleaned as necessary. Failure to properly clean the lint screen may result in inadequate air flow and faulty operation of the CTMD.

CAUTION: *Operation of the CTMD with a clogged or improperly installed lint filter can result in damage. Care must be taken to ensure the filter is cleaned regularly.*

THEORY OF OPERATION

This section explains in detail the various functions, features and control sequences of the CTMD. Knowledge of these details will assist the operator and service personnel to understand how the functions interact, interpret process results and diagnose operational difficulties. Refer to the attached schematic drawings for further details in conjunction with the discussion below.

Dielectric Heating

Microwave, or dielectric heating occurs when electromagnetic fields oscillating at a specific frequency (2450 MHz) interact with certain kinds of molecules (having a high dipole moment). These molecules try to align themselves with the electric fields as they rapidly reverse polarity at the oscillating frequency, causing them to vibrate. The resulting friction between adjacent molecules generates heat.

Materials containing highly polar molecules are said to be “lossy” because they readily absorb microwave energy. A measure of this lossiness is a property of the material known as its dielectric loss or loss tangent. Water is a good example of a lossy material because its molecules have a high dipole moment. Most fabrics are made of materials having a relatively low dielectric loss, far lower than that of water.

In the microwave fabric dryer microwave energy is absorbed primarily in the water rather than the fabric, resulting in heating and vaporizing of the moisture. The fabric tends to stay relatively cool because it is not being heating directly. By contrast, the hot air used in conventional dryers heats the fabric and the moisture simultaneously, resulting in higher overall drying temperatures.

However, as moisture is vaporized and leaves the microwave dryer the tendency to heat the fabric directly becomes greater. If microwave energy remains on after the moisture has been removed then damage to the fabric from burning could result.

Microwave Power Generators

The microwave power generator used in the CTMD consists of two main elements, a magnetron oscillator and a high voltage power supply. The magnetron is a vacuum tube oscillator that is designed operate at the desired frequency (2450 MHz). Like other types of vacuum tubes it contains an anode, a cathode and a filament (heater) and operates when the filament is hot and a sufficiently high voltage is present across the anode and cathode.

High voltage, also referred to as the “plate” voltage, supplied to the magnetron is generated in the CTMD using a “half-wave voltage doubler” power supply. This power supply is identical to power supplies used in conventional microwave ovens.

Field Strength Sensor

The field strength sensor monitors the electric field strength inside the dryer cavity. It operates by sensing the microwave field using a small wire probe and converting the signal to a DC voltage using a crystal diode. The microprocessor monitors the field strength signal and controls the amount of microwave power as required to prevent damage.

The field strength varies with the level of microwave power delivered to the cavity and the amount of moisture (and fabric) inside the cavity. If the field strength is too high then damage could result to the fabrics and/or dryer.

At the beginning of the drying process moisture content is generally high, thus the field strength is relatively low. As the drying process progresses and moisture is removed from the dryer cavity the field strength gradually climbs. Full loads are preferred to light loads so as to maintain the electric field strength at relatively low levels throughout the drying process.

As the basket rotates and the fabrics tumble inside the dryer cavity the electric field pattern is constantly changing. Thus, the electric field seen by the field strength sensor is constantly changing and results in wide variations of the output signal. The peak values typically remain well below the setpoint values at the beginning of the drying cycle, but towards the end of the cycle they can easily exceed the setpoint values while the more important time averaged value is still below the setpoint. To help compensate for these variations the microprocessor calculates the average value of the 25 most recent field strength readings and uses the result for the interlock function.

Exhaust Gas Sensors

A series of four sensors monitor the exhaust air for the presence of specific compounds commonly found in smoke or other products of combustion. Each sensor is designed to detect a different set of compounds as defined in the following chart:

Gas Sensor Compound Sensitivity		
Sensor Number	Figaro Type	Compounds Detected
1	822	Toluene
2	825	Hydrogen Sulfide
3	842	Methane, Propane, Butane
4	882	Alcohol

The sensors operate by passing a current through a selective adsorbent element whose resistance varies as compounds are adsorbed. The output voltage varies with this resistance and increases as compounds are adsorbed. The microprocessor monitors the output voltage and triggers the gas sensor fault cycle (see Basic Operation section) when its slope exceeds a preset value.

The sensor elements operate most effectively at an elevated temperature, thus a heater voltage (+5 VDC) is supplied in addition to an instrument voltage (+3.3 VDC). These voltages are supplied whenever line power is connected to the CTMD and the main circuit breaker is turned on. A warm-up period of up to one hour is required for stable and reliable operation of the sensors.

Sensor Lint Screen Burn-off

To protect the exhaust gas sensors from fouling due to lint accumulation, a lint screen separates the sensors from the flow of air in the exhaust duct. But if lint is allowed to accumulate on this screen then it will gradually reduce the flow of exhaust air to the sensors, thus reducing their sensitivity.

To prevent continual accumulation of lint on the sensor screen the lint is burned off at the beginning of every drying cycle by applying an electrical current through the screen. This current is high enough to cause the lint to smolder but not ignite into an open flame. The burn-off period occurs before the blower starts so that the flow of air does not prevent the burn-off temperature from being reached. The lint ash is then carried away by the exhaust air.

Low Voltage Power Supplies

Several low voltage power supplies provide power to various control circuits. These power supplies are on whenever line power is connected to the CTMD and the main circuit breaker is turned on. Their functions are described as follows:

- 24 VDC Power Supply – This power supply provides power to the basket motor only. The output voltage passes through a

variable voltage regulator located on the control PC board. The output of this regulator can be varied to control the basket rotation speed.

- 5/12 VDC Power Supply – This power supply provides voltage to the microprocessor controller and PC board.

USER MAINTENANCE

The CTMD is designed to relatively maintenance free. With the exception of the lint screen, there are no operator serviceable parts or subassemblies inside the CTMD.

WARNING: *Lethal voltages may exist inside the CTMD even during periods of non-operation. All service personnel must be aware of the hazards involved with high voltage electrical circuitry and high power microwave devices. In the event service becomes necessary, all repairs should be performed by a qualified service technician.*

Lint Screen Cleaning

The lint screen, located inside the panel beneath the cavity door, should be inspected regularly and cleaned as necessary. Failure to properly clean the lint screen may result in inadequate air flow and faulty operation of the CTMD.